DEVICE, METHOD AND HEADPHONES FOR REGISTERING AND REPRODUCING NOISES, IN PARTICULAR FOR ANALYSING ACOUSTIC COMPONENTS IN MOTOR VEHICLES

BACKGROUND OF THE INVENTION

Field of the invention

[0002] The invention concerns a device and a process for registering and reproducing sounds, in particular for acoustic component analysis in motor vehicles. The invention also concerns headphones, in particular for use with the inventive device and the inventive process.

Related Art of the Invention

[0003] German Patent Document DE 195 31 402 C2 discloses a device and a process for recognition of defects in a motor vehicle. For analyzing defects, vibrations in a passenger compartment of a motor vehicle are detected and compared with recorded vibration patterns, wherein various vibration patterns are stored in memory for various operating conditions of the motor vehicle. Defective components produce their own resonance frequency, and by comparing detected vibration patterns with the stored vibration patterns a defect can be recognized. The analysis of the compared vibration patterns occurs on the basis of a frequency analysis with production of a summed spectrum of stored vibration pattern and detected vibration pattern.

[0004] From the German laid open document DE 198 44 784 A1 a process is known for identifying a noise perceived subjectively by an operator, in which a sound of the motor vehicle, which is subjectively found to be disturbing by the operator, is recorded. The recognition of the sound occurs preferably binaurally. By means of signal follow-up processing outside of

the vehicle, the background sound is played to the user via headphones and the user is asked to identify the disturbing sounds. The identified disturbing sound is subjected to a frequency analysis and is manipulated in the manner that certain frequencies or groups of frequencies are either amplified or attenuated. The manipulation occurs by means of filtering. The manipulated frequency spectrum is back transformed in a time signal and again played to the operator. The operator is then asked to evaluate whether the disturbing sound is still present. Based on the evaluation by the operator, an appropriate measure, in particular a repair of the vehicle, is undertaken.

SUMMARY OF THE INVENTION

[0005] With the present invention a device and a process for registering and reproducing sounds, in particular for acoustic component analysis in motor vehicles, is improved.

[0006] In accordance with the invention there is provided for this a device for registering and reproducing sounds, in particular for acoustic component analysis in motor vehicles, with at least two microphones to be provided in the vicinity of the two ears of a user for the binaural detection of sounds for the conversion into electrical signals, with two sound protection devices - for example having a sound dampening of 20 dB at frequencies above 250 Hz - for provision in the vicinity of the two ears, for shielding the two ears from the detected sounds, with signal processing means for real time processing or real time reproduction of the produced electrical signals, and with two sound transducers adapted to being provided in the vicinity of the two ears for the binaural real time production of sound signals according to the relayed or processed signals.

[0007] By means of the inventive device, detected sounds can be filtered in real time, manipulated and realistically reproduced. By means of the invention the prerequisites for a real time evaluation of sounds are accomplished. Processes which have been known until now, which are complex, are hereby substantially simplified, so that a useful application in development and research arenas is actually made possible for the first time. A substantial advantage of the invention is that the signal processing occurs in real time and therewith no time consuming post processing of data need be undertaken. Rather, in the case of a motor vehicle, a sound can be manipulated in real time and reproduced anew during a test drive.

[0008] As a further development of the invention, the signal processing means includes devices for reducing or increasing the sound level emitted by the sound transducers in comparison to the sound level detected by the two microphones.

[0009] In this manner a real time evaluation of even very strong or very soft sounds or sound components becomes possible, which could not be meaningfully evaluated by the human ear alone. Preferably the passive shielding by the ear covers can be supplemented or combined with a low frequency, for example 16-300 Hz, active sound reduction system with a destructive interference - as known from headsets for airplane pilots. Therewith, low frequency chassis sounds as well as the low frequency motor components are strongly attenuated. High frequency components, which are difficult to attenuate by

interferometrics, are sufficiently attenuated by the passive shielding provided by the ear covers.

[00010] As a further development of the invention the signal processing means include filter devices for suppressing the frequency range of the detected sound, wherein frequency ranges can be suppressed which are either constant or variable over time.

[00011] In this manner a component analysis is made possible by suppressing critical components such as motor systems or resonance frequencies during a test drive.

[00012] As a further development of the invention, the signal processing means include control devices for controlling the filtering devices depending upon operating parameters of a further system, in particular an object being examined or a motor vehicle.

[00013] For example, a control or actuation of the filtering device can occur in response to a rotational speed signal, a vehicle speed or the switching on signal of a ventilator or a turbo charger. The control of the filter devices can also occur depending upon a further sensor, for example a body acoustic noise or sound sensor.

[00014] As a further development of the invention the control devices include means for constituting neural networks and/or fuzzy logic.

[00015] Thereby the presentation of artificial intelligence is made possible.

[00016] In a further development of the invention data banks are provided, in particular for storage of sound patterns.

[00017] In this manner it becomes possible to store, for example, sound patterns for comparison and for documentation of development intermediate results.

[00018] In a further development of the invention synthesizing devices are provided for production of sound patterns from the registered sounds.

[00019] By these means, the presentation of a desired audio impression is made possible and the evaluation of the influence of changes of components upon the emitted sound.

[00020] In a further development of the invention the signal processing means include mixing devices for mixing in produced sound patterns and/or stored sound patterns for the further processing or for the production of signals.

[00021] In this manner a sound impression can be simulated, for example a sound impression which results in a case of outfitting a motor vehicle with special equipment.

[00022] In a further development of the invention the mixing devices are controlled depending upon operating parameters of a further system, in particular an object being examined or a

motor vehicle. Neural networks and fuzzy logic can be employed for control.

[00023] In a further refinement of the invention at least one communication interface is provided.

[00024] In this manner data can be relayed to, or be received from, further systems. For example, the controlling or monitoring of further sub-systems is made possible. For example, driving programs can be produced, which undertake an operation of transmission, motors and in certain cases ventilators for a minimizing of the sound interference.

[00025] The problem addressed by the present invention is also solved by a process for registering and reproducing sounds, in particular for acoustic component analysis in motor vehicles, which process includes the following steps: Binaural registering of sounds in the vicinity of the two ears of a user and transformation into electronic signals while shielding the two ears from the sounds, processing or relaying the generated electrical signals in real time, and binaurally producing sound signals in the vicinity of the two ears in real time corresponding to the relayed or processed signals.

[00026] In this real time processing, the filtering for suppressing can be of frequency regions which are constant and/or variable over time.

[00027] The filtering can occur depending upon operating parameters of a further system, in particular an object to be

examined or a motor vehicle and in certain cases with employment of neural networks and fuzzy logic.

[00028] A synthesizing of sound patterns from the registered sounds can be provided as was the mixing of registered, synthesized and/or stored sound patterns. The mixing can occur depending upon operating parameters of a further system, in particular an object being examined or a motor vehicle, wherein the mixing can occur with employment of neural networks and/or fuzzy logic.

[00029] Further, data exchange and/or communication with further systems can occur.

[00030] The problem addressed by the invention is also accomplished by headphones, in particular for employment in the inventive device and the inventive process, with two shielding casings for human ears and respectively at least one sound transducer in each shield casing, wherein at least one microphone is provided on each shield casing on the side of the shield casing opposite to the ear.

[00031] By means of such headphones, there is on the one hand made possible a realistic detection of sounds, and the reproduction of the associated, in certain cases manipulated, sounds. Thereby, for example, during a test drive in a motor vehicle the sound impression can be manipulated in real time. What is essential is that with the invention in real time, and therewith essentially simultaneously, sounds can be realistically detected and reproduced, for example binaurally.

[00032] In a further development of the invention, on each shield casing, on the side opposite to the ear, a simulated human ear is provided, in which area the microphone is located.

[00033] By this means an audio-corrected detection is made possible in the manner of an artificial head.

Brief Description of the Drawings

[00034] Further characteristics and advantages of the invention can be found in the claims and the following description of a preferred embodiment of the invention in conjunction with the figures. In the figures there is shown:

Fig. 1 a schematic block diagram of the inventive device,

Fig. 2 a further schematic representation of the inventive device with an inventive headphones and,

Fig. 3 a schematic logic or flow diagram of an inventive process.

Detailed Description of the Invention

[00035] The representation in Fig. 1 shows the inventive device, which includes two microphones **10**, **12**, which are provided in the vicinity of the two ears of a user. The microphones **10**, **12** detect sounds at the two ears of the user and relay these to a real time processor **14**. In the real time processor **14** the signals supplied by the microphones **10**, **12** are processed or essentially looped through. For example, the sound level can basically be reduced or increased. The processed or looped through signals are then provided to second sound

transducers **16**, **18**, which convert the obtained electrical signals into audio signals. The sound transducers **16**, **18** are, respectively, provided within one of the ear casings of a headphone. By means of the microphones **10**, **12**, which are provided outside on the ear casings, and the sound transducers **16**, **18** within the ear casings, a binaural (stereo) sound detection and sound reproduction can occur. The sound detection and the sound reproduction occur essentially simultaneously, in certain cases with an intermediate real time processing of the signals in the real time processor **14**.

[00036] With the inventive device a test person, when in the presence of an environment with sound influence, can be provided with an overall authentic auditory situation. By means of the real time processor **14** it becomes possible, as desired, to filter out specific components of the total sound in real time for the test person. Thereby, a real time identification of the source of sounds is substantially made easier for the test person. This is of substantial interest in particular in the development and maintenance work for motor vehicles. Thus, sound sources in motor vehicles, or generally also technical devices, can be detected or identified by means of the inventive device.

[00037] In the case of high dynamic systems, such as for example a motor vehicle internal combustion engine, it may occur that during operation frequently tonal sound components occur which, despite their relatively low level, dominate the character of the total sound. Frequently such tonal sound components are the basis for client complaints. The technical origin of these tonal sound components often lies in the

periodicity of mechanical or hydraulic occurrences, which are in a fixed relationship to the motor rotational speed. The motor rotational speed itself is characterized as a base order or first order. A meshing sound of a chain drive with, for example, 18 teeth on the gear wheel thus produces in typical manner the so-called 18^{th} motor order.

[00038] If a vehicle is subjected to high tonal sound components, so-called howling noises, then it is frequently not possible by a subjective evaluation by the human ear alone to recognize the frequency location of the tonal sound component with sufficient precision. A frequency analysis carried out following the recording can precisely analyze, besides static tones, also dynamic tones, for example motor orders or harmonics, on the basis of the synchronized detection of the motor rotational speed, and assign the technical cause. A tonal sound component or a so-called howling noise can be radiated out by hydraulic components of the oil pump, by chain meshing or the generator. By carrying out of the frequency analysis a howling sound can be attributed to a particular motor component and possibly a sound producing subassembly.

[00039] With the inventive device such an analysis of sounds can occur in real time, so that for example during a test drive motor orders or harmonics are selectively filtered out, in order under realistic conditions, with special acoustic correct, detection, and reproduction of sounds, to determine the cause of disturbing sounds. By means of the real time processor **14** a signal processing of the electrical signals supplied by the microphones **10**, **12** is carried out. For this, there occurs by means of the real time processor **14**, for example, a digital

frequency analysis and a filtering of the obtained frequency spectrum for suppression of frequency ranges of the detected sounds. Thereby frequency ranges can be suppressed which, viewed over time, can be either constant or variable. For example, as already described, it becomes possible to suppress motor orders or also frequency regions which are constant viewed over time, such as resonant frequencies of critical components.

[00040] By means of the real time processor **14** the manipulated frequency spectrum is again converted into a time signal and emitted by the sound transducer **16, 18.**

[00041] In order to be able to suppress for example motor orders, the real time processor **14** obtains input data from a further system or subsystem **20**, for example an internal combustion engine of a motor vehicle. Generally, operating data is made available by the subsystem **20**, which could include for example the motor rotational speed, a vehicle speed, an on/off condition of blowers, the charge pressure of a turbo charger, or the like.

[00042] The real time processor **14** further obtains input signals from a reference sensor **22**. One such reference sensor could be for example a body sound sensor, which is attached to a suspect component. By means of the real time processor **14** the sound component attributed to the body sound of the suspect component can be selectively filtered out, in order to be able to assess in real time the subjective detectable contribution of the suspect component to the total sound. The reference sensor **22** can however for example also be in the form of a microphone which is provided outside of the vehicle passenger compartment.

In this manner for example the audible influence of wind sounds, wheel rolling sounds and exhaust pipe sounds can be examined.

[00043] Further, the real time processor **14** can exchange data with a data bank **24** and obtain data from this data bank **24**. The data bank **24** is provided for the storage of sound patterns, which are collected by means of the microphones **10**, **12**. The collected sound patterns can in certain cases be filtered. Further, synthesized sound patterns are stored in the data bank **24**, which were produced on the basis of sounds registered by means of the microphones **10**, **12**. Further, the data bank **24** can be used for storage of sound patterns, which are based completely upon simulation or which were collected from a system other than the subsystem **20**.

[00044] The sound patterns stored in the data bank **24** can, in real time, be superimposed with the sounds which were registered by means of the microphones **10**, **12**. As a result of such a mixture of sound patterns, auditory impressions can be simulated. For example, an audio impression can be simulated, which would be produced when a motor vehicle is equipped with specific special equipment or another variant of a used or installed component. The mixing in of stored sound patterns can occur for example with control from operating data of the subsystem **20** or from signals of the reference sensor **22**. Further, the mixing in of sound patterns from the data bank **24**, as well as the filtering of the detected sounds within the real time processor **14**, can be controlled using artificial intelligence, produced by neural networks or fuzzy logic.

[00045] Finally, the inventive device can be equipped with a communication unit **26**, via which a data and signal exchange with further systems can occur. Additional systems could be controlled or regulated by the signals from the real time processor **14**. For example, the real time processor 14 can provide signals to a motor controller via the communication unit **26**, in order to operate an internal combustion engine as quietly as possible.

[00046] In the illustration according to Fig. 2 the device of Fig. 1 is shown in detail, and in particular the arrangement of the microphones **10**, **12** and the sound transducers **16**, **18** on an inventive headphone **28** can be seen. The headphones **28** include in a conventional manner two shield casings **30**, **32**, which are connected to each other via a support bracket **34** and respectively shield one ear of the user **54** against environmental sounds. Within shield casing **30** the acoustic transducer or loudspeaker **16** is provided, and within shield casing **32** the sound transducer or loudspeaker **18** is provided.

[00047] On the outside of the shield casings **30**, **32**, on the side opposite to the shielded ear of the user **54**, there is provided respectively one artificial outer ear **36**, **38** or a suitable device for sound transformation, in conjunction with which the spatial directional characteristics of an outer ear can be achieved. The microphone **10** is provided within the artificial outer ear **36**, which is provided on the shield casing **30**, and the microphone **12** is provided within the artificial outer ear **38**, which is provided on the shield casing **32**. By means of the artificial outer ears **36**, **38** and the microphones **10**, **12** an acoustically correct, binaural detection of an

environmental sound is made possible, which is indicated using the double arrows **40**. In the schematic representation in Fig. 2 the artificial outer ears **36**, **38** are shown not to scale. It can be seen that in the sense of a realistic as possible auditory impression the artificial outer ears **36** are to be provided as close as possible to the head or to the ears of the user **34**.

[00048] The sounds collected by the microphone **10**, **12** are transformed into electrical signals and supplied to the real time processor **14**. The real time processor **14**, which can also be referred to as a sound processor, carries out an analysis of the electrical signals corresponding to the collected sounds. It includes at least one order filter, at least one static filter and can beyond this create a documentation of the detected sounds and carried out manipulations. For example, appropriate data can be deposited in the data bank **24** or be provided to a display device.

[00049] As already described, the real time processor **14** obtains operating data from a further system, in the illustrated case a motor vehicle **22**. From the motor vehicle **22** for example a rotation counter signal (RPM) can be supplied as the trigger or driving signal. The real time processor **14** is further provided with a conventional second headphone outlet **42**, which enables the simultaneous hearing of the collected or manipulated sound.

[00050] The signals filtered and in certain cases further manipulated by the real time processor **14** are supplied to a sound transducer **16**, **18**, which produces audible signals and emits these within the shield casings **30**, **32** in the direction

towards the ears of the user **34**. The user **34** obtains thereby an audio realistic reproduction of the filtered and in certain cases further manipulated sound. In order to achieve a good as possible shielding by the shield casings **30**, **32**, these preferably lie sealed against the head of the user **54** via a flexible seal **44**.

[00051] The inventive headphones **28** combine therewith a binaural head spanning microphone, which in similar design is known from acoustic artificial head measurement technology, with closed headphones with strong shielding. The auditory detection occurs via a microphone with artificial outer ears, similar to an artificial head. The microphones **10**, **12** with the artificial outer ears **36**, **38** are provided directly on the outer side of the shield casings **30**, **32** and as close as possible to the ears of the user **34**, in order to provide the authentic auditory sense. In the basic embodiment of the inventive device, in which the real time processor **14** provides the collected sounds without manipulating filtering, however with an auditory trueness correction, to the sound transducers **16**, **18**, the user **54** has essentially the same auditory impression as though he was not carrying any headphones **28**. If the detected signals are manipulated by the real time processor **14**, there is produced for the user **54** the authentic recognition of the remaining sounds without the targeting suppressed components.

[00052] In the following examples of application are provided for the inventive device and the inventive process.

[00053] When driving a motor vehicle with a turbocharged internal combustion engine, two sound components project in

particular out of the total sound. On the one hand, as a consequence of the gearing of the chain drive of the cam shaft the 18^{th} motor order (harmonic) can be heard. On the other hand following rapid reduction in load the spinning down of the turbo charger, of which the rotational speed has no fixed relationship to the motor rotational speed, becomes conspicuous. By means of the inventive device, taking into consideration the rotational speed of the motor, a banned block filter can be imposed upon the 18^{th} motor order (harmonic). Thereby the 18^{th} motor order can be suppressed, without impeding recognition of remaining sounds via the closed headphones **28**. Thereby the howling sound of the chain drive cannot be heard at any rotational speed and the comparison with the unfiltered signal identifies the sound causing component, namely the chain drive.

[00054] Since the rotational speed of the turbo charger has no fixed relationship to the rotational speed of the motor, its howling noise cannot be suppressed by a simple motor harmonic filter. For targeted control of the necessary banned block filter the rotational speed of the turbo charger must be detected for example via a body audio sensor, corresponding to a reference sensor **22**. Thereby the necessary filter parameters can be determined in the real time processor **14** and the howling sound of the turbo charger can be filtered out.

[00055] By the real time processing of the signals in real time processor **14** a comparison of the unfiltered and the filtered sounds can occur at the real object, without requiring a time delay or a reproduction on display devices. Thereby, assessments are simplified and product development cycles can be shortened.

[00056] As a further example, the use of separate microphones or other sensors is mentioned. Such separate microphones or further sensors can be provided in the near proximity of a suspect sound source so that sound patterns of this source can be collected. Since these collected sound patterns are provided to a real time processor **14**, this can filter sound patterns typical for the sound source out of the transmission path between the microphones **10**, **12** and the acoustic transducers **16**, **18**.

[00057] Besides the filtering out of sound patterns, the possibility of adding in of other sound patterns from the data bank **24** allows the simulation of the exchange of acoustically realistic aggregates in real time, for example during a test drive.

[00058] The representation according to Fig. 3 shows schematically an embodiment of the inventive process. In step **46** the binaural detection of the sounds occurs by means of the microphones **10**, **12**, which are provided on the artificial outer ears **36**, **38** and thus, when the user **54** is wearing the headphones **28**, in the vicinity of his two ears. The microphones **10**, **12** convert the collected sounds in step **46** into electrical signals and provide these to the real time processor **14**.

[00059] The real time processor **14** carries out in step **48** a real time processing of the electrical signals collected by the microphones **10**, **12**. For example basically a sound level can be increased or reduced or the signals can be emitted without change again at the sound transducer **16**, **18**. Conventionally

however there occurs a Fourier transformation of the time signals obtained by the microphones **10**, **12**, a filtering, or other manipulation in the frequency region.

[00060] In step **48** also a synthesizing and storage of sound patterns from the sound patterns collected by means of the microphones **10**, **12** can occur.

[00061] In optional step **50** there can occur a mixing of the sound patterns registered by the microphones **10**, **12**, and in certain cases manipulated in step **48**, with stored sound patterns, in time or frequency range.

[00062] In the following step **52** the likewise filtered and manipulated electrical signals are emitted following back transformation in the time range at the sound transducers **16**, **18**, which thereupon create a binaural and auditory realistic production of sound signals.

[00063] It is essential that in the invention the subjective influence of changes of the sound pattern can be appraised, since a binaural collection and reproduction of sound signals occurs while taking into consideration the sensitivity curves of the human range of hearing. Since detection, manipulation and reproduction of sound patterns occurs essentially simultaneously in real time, sounds can be examined under realistic test conditions, for example during a test drive. This is of substantial importance for the subjective appraisal of sounds, of which the authenticity depends in perceptible manner on the sum of all environmental conditions, such as the seat vibration, acceleration feel and correlation with the vehicle conditions,

for example shifting, giving gas. Thereby in motor vehicles, in particular prototypes with intrusive noises, the sound can be simulated in a virtual drive train.

[00064] Thereby it becomes possible to cleanse the hearing situation present in each vehicle of disturbing sound components and supplementally to enrich or amplify, in direct correlation to the operating conditions of the vehicle, for example synthetic and/or sampled sound components. Therewith there results the possibility to test drive a virtual motor. In particular, one typical sports car sound is producible by recognized mixed-in sound components with appropriate rotational dependency and load dependency, so that this can be directly experienced in the authentic environment of the vehicle. Thereby the targeted or desired sound is realizable long before the future motor is even run on the test stand.